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Effect of Cultural Methods and Maturity Upon the Seed Value of Eastern Nebraska Potatoes

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COLLEGE OF AGRICULTURE UNIVERSITY OF NEBRASKA
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SUMMARY

Seed potatoes of the Early Ohio and Irish Cobbler varieties were produced and tested at Lincoln thruout a period of 7 years under a variety of conditions. Studies were made of time-of-planting and time-of-harvesting, cultivation and straw mulching, irrigation and no irrigation, and growing of plants under insect-proof cages and in the open as well as in isolated and non-isolated plats and rogued plats. The spindle-tuber content varied from practically nothing in some stocks to a high percentage in others.

Early planting, straw mulching, and irrigation were all practically certain to increase the current crop yield. During practically any season and with any cultural system, planting in April would permit at least 75 per cent of the crop to be harvested by the middle of August. Spindle-tuber was less apparent in the straw-mulched than in the cultivated plats.

Late planting—that is, in late May and June—resulted in such a greatly reduced yield as to render such practice impractical under eastern Nebraska conditions. The yield from late planting was greater with a straw mulch than with ordinary culture.

A few data are supplied concerning the composition of potatoes grown under the different conditions.

When spindle-tuber was present in the Lincoln plats to the extent of 5 per cent or less, the increase of the disease varied in the different lots according to the culture. The disease content increased more in cultivated than in straw-mulched stocks and more in early than in late plantings.

When seed lines infected with spindle-tuber were planted in comparative plats, straw-mulched stocks were more productive than cultivated stocks, and late-planted or early-harvested stocks were superior to early-planted or late-harvested lines respectively. Late planting produced seed superior to that of approximately the same maturity but secured by early harvesting. Planting and harvesting dates affected the seed more when grown with cultivation than when straw mulched. Irrigation was a negligible factor in these experiments insofar as seed-potato productivity was concerned. Seed stocks that had "run out" at Lincoln due to spindle-tuber infection were not rejuvenated by straw mulching.

When healthy seed stocks were grown in isolated places or maintained in a healthy condition by growing parent plants under insect-proof cages, the yield differences were much less than when spindle-tuber was present. Late-planted was somewhat more productive than early-planted stock and straw-mulched stock was slightly superior to cultivated stock. The degree of dormancy of the seed tubers at planting time and the occurrence of tuber production at a favorable or unfavorable climatic period in the trial year were factors which

influenced yield. The former would continue more or less constant; the latter might vary from year to year. The soil nitrate content did not appear to influence seed-potato productivity.

When good seed stock—with less than 1 per cent of spindle-tuber—was planted in eastern Nebraska, its product was satisfactory for use as seed stock. After a second year in eastern Nebraska its seed value was small, owing to spindle-tuber increase.

Effect of Cultural Methods and Maturity Upon the Seed Value of Eastern Nebraska Potatoes

H. O. WERNER

Distinct deterioration or degeneration of seed stocks has for some years been considered the inevitable result of growing seed potatoes in the states located south of, or at a lower altitude than that of, the states producing late potato crops. Until comparatively recently this degeneracy was attributed to the unfavorable effects of environmental conditions upon the tubers. Extensive research during the last ten years has shown that generally the presence and rapid spread of one or more virus diseases is the major or possibly sole cause of this deterioration or "running out" of seed stocks. The spread of these virus diseases is undoubtedly quite distinctly influenced by environmental conditions. An important phase of the seed-stock deterioration problem is the determination of the influence of environmental or cultural conditions and maturity upon healthy seed potatoes.

THE SEED-POTATO PROBLEM IN EASTERN NEBRASKA

For many years the buying of northern-grown seed potatoes has been an established practice in the early-potato regions located in the eastern, central, and southern parts of Nebraska, as well as in the other corn-belt states and also in the South. Seed potatoes grown in these regions have almost uniformly been found to be less productive than northern-grown seed stocks. In eastern and southern Nebraska at least, this difference has been apparent after only one year of culture and has increased with each additional year.

Seed potatoes as good as northern stocks have been produced under a straw mulch in eastern Nebraska by experimenters and growers. Occasionally reports are heard that a lot of seed potatoes has been grown in eastern Nebraska by ordinary cultural methods for many years, apparently without loss of vigor or yielding capacity.

In view of this situation it seemed advisable to investigate this problem to determine whether, and to what extent, environment and maturity as such influence the productivity of seed potatoes and also whether it is feasible to produce satisfactory seed potatoes in the southern and eastern portions of Nebraska.

HISTORICAL REVIEW

The literature dealing with the effect of environmental conditions upon seed potatoes extends back over a period of many years. Much

of it has little value here because of the lack of knowledge of potato diseases at the time the earlier work was conducted. The review will therefore be limited to work which is relatively recent and which has a reasonably direct relation to the special phase of the problem which is considered herewith.

RELATION OF CULTURAL CONDITIONS TO SEED VALUE

Emerson (1914) reported that the original productivity of seed potatoes secured from the north was maintained at Lincoln when the potatoes were grown under a straw mulch. He also reported the rejuvenation of degenerate stocks by means of straw mulches. It should be noted that practically all of this work was conducted before virus diseases were recognized in this country. Wessels and Hartwell (1927) reported increased yields from straw-mulched as compared with cultivated stock.

In some portions of the country growers have a prejudice against irrigated seed potatoes. A number of workers have given reports on irrigated *versus* dry-land seed potatoes. Their reports are not discussed here because all these pieces of work dealt with late potatoes in the main crop-potato districts and none was conducted in the warmer areas, where it is practical to grow potatoes only as an early crop.

Parker (1922), Appleman (1924), Rosa (1925), and Salaman (1926) suggested or inferred that droughty conditions have injurious effects upon seed potatoes, but none of them supplied any supporting data. During the last ten years the author several times has planted lots of seed potatoes that had been grown under as droughty conditions as will permit plants to live and produce tubers, yet the seed value or productiveness of these lots was apparently unimpaired. Wellenseik (1925) reported that dryness during the last week of tuber growth stimulated early, vigorous germination of the seed potatoes. Tubers thus produced by him were probably ripened prematurely and consequently completed their period of dormancy at an earlier date than did the tubers from plants that did not have their growth checked by drought.

Emerson (1914) reported higher yields from seed potatoes produced by planting parent seed pieces at a depth of 7 inches than from those whose seed pieces were planted at a depth of 4 inches and 1 inch. Müller and Molz (1924) reported that shaded plants produced higher-yielding seed tubers than unshaded plants. They suggest that in such tubers certain substances, especially ferments, remain inactive in the tubers after they are lifted and cause an early growth of vigorous and high-yielding plants. They suggest also that possibly close planting will accomplish the same results as shading.

These same authors (1924) reported increased yields from seed stocks produced by plants provided with the least area per plant. Under such conditions relatively small seed tubers undoubtedly were

produced. Probably the following season many such tubers were planted whole or if they were cut into uniform seed pieces there were more eyes per seed piece than were found in the seed pieces from the larger potatoes produced by the plants provided with more space. Consequently yield differences may have been due to seed-tuber size differences and not to any change within the tubers.

Wessels and Hartwell (1927) reported that when healthfulness was not affected, seed potatoes produced under growth-limiting conditions, such as too acid a soil, a lack of nutrients, etc., gave the larger yields. They called attention to the possibility that part of this increase may have been due to the smaller size of the tubers produced under unfavorable conditions and the consequent larger number of eyes per seed piece of any given size.

Janssen (1929) reports that infection of mosaic and leafroll occurred to a greater extent in lots of seed potatoes grown on sandy than when grown on clay soils. Seed lots produced on these soils became most heavily infected when given either a complete fertilizer or one lacking potash, while the least infection was in the lots produced with a nitrogen shortage. In controlled greenhouse experiments he found that altho nitrogen-deficient plants were only one-third the size of high-nitrogen plants, the former were less easily infected and more time was required for their tubers to become infected. By means of careful counts they found that aphids increased most rapidly on the potash-deficient plants (evidently because of sugar accumulation in the leaves) and least rapidly on nitrogen-deficient plants (probably because of the tough leaf cuticle).

Recent research has shown that seed-potato productivity can be maintained in regions where it is commonly supposed that high productiveness cannot be maintained. Bushnell (1928) has shown that lots of potatoes have been maintained in Ohio for over 90 years without any indication of "degeneracy" of any kind. Brown (1928) has shown that in Connecticut seed potatoes kept free from disease by continual production under insect-proof cages retained their original productivity in a region where degeneracy of seed stocks in open fields is very rapid.

In these various studies there seems to be no evidence that cultural methods influence seed stocks when disease is not present, except as they may influence the period of tuber dormancy or the number of eyes per seed piece.

RELATION OF MATURITY OR IMMATURITY TO SEED VALUE

In Europe immature seed has long been considered superior for seed purposes. Knight is credited (Salaman, 1926, p. 41) with being the first to make an authoritative statement (in 1813) that immature seed was a means of combating degeneration. Among the more or less recent reports is that of Münter (1922) who cites London, Low, Aitkins, Nobis, Ramsay, and Hutchinson as having demonstrated the superiority of immature seed for planting. Concerning his own work

he reports that immature seed contained less disease and germinated earlier than mature seed. Bötjes in two reports (1923), referring not only to his own work but also to that of Münter, of Molz, and of Hilton, shows that the shortened season in the field provides less opportunity for virus disease infection and therefore is the prime reason for larger yields from unripe seed. Furthermore, the date of harvesting is of less significance than whether infection occurred early or late in the season. This latter idea accounts for some discordant results such as those of Profeit (1923) reporting that in his work in Scotland time of harvesting had no effect on the amount of leaf roll and mosaic. Schultz and Folsom (1923) and Folsom (1924) showed that in Maine late-harvested potatoes acquired more infection than those harvested early and were consequently less productive. Werner (1924, 1925) showed early caging and early harvesting to be of some value in reducing infection and increasing yields in healthy stocks interplanted in fields heavily infected with spindle-tuber. In 1923, however, infection occurred so early as to render these practices valueless. Edmundson (1922, 1924) did not secure any significant differences in yield by harvesting seed at different dates when using a healthy lot of the Rural New Yorker variety at Greeley, Colorado. However, he stated that really fully mature seed is not produced at Greeley because of early frosts. Butler (1926) reported improved yields and decrease in virus diseases by early harvesting in New Hampshire. Werner (1925) showed that at North Platte, Nebraska, immature seed, whether acquired by early harvesting or late planting, was most productive due to a lower percentage of spindle-tuber infection. The degree of infection was in direct proportion to the number of days the parent plants were in the field, but a given number of days in the field late in the season were more effective for the production of disease-free seed than the same number early in the season.

Knorr, quoting data secured at Bernburg, Germany, reported (1922) that tubers harvested before the vines were ripe or later, from plants where tops had been cut while green, produced a higher yield the next year than those that were allowed to remain until the vines ripened naturally. Similar results are reported by Müller and Molz (1924).

Stuart *et al.* (1927) reported slightly greater yields from mature seed at Norfolk, Virginia, and also at Presque Isle, Maine. On the other hand, immature seed was slightly more productive at Greeley, Colorado, and decidedly more productice at Jerome, Idaho. Since they do not supply information concerning virus-disease prevalence, it is impossible to determine to what extent these results may have been due to disease.

Appleman and Miller (1926) analyzed potatoes harvested at different stages of maturity. These analyses were made at harvest time

and at the end of the rest period. Their conclusion is: "The data in this paper do not reveal any chemical or physiological basis for the superiority of immature potatoes for seed. The cases reported of immature seed giving better results than mature seed may have been due to a greater freedom from degeneration diseases in the immature seed." They did not report any data to substantiate the latter conclusion.

Rosa (1928) called attention to the fact that "the more nearly mature potato tubers are when harvested, the shorter is the dormant period, as indicated by more rapid sprouting when they are cut and planted." He also reported that the primordia of vegetative sprouts develop during the later stages of tuber growth as well as during the dormant period. The relation of seed maturity to yield, therefore, may be influenced by the length and condition of storage before the tubers are planted.

Immature seed harvested very early or late presents a greater storage problem than mature seed harvested at the time customary for storing potatoes. There is also considerable variation in the length of the storage period after the rest period has been completed. These two factors, which have not received consideration in studies of immature seed, might have decidedly practical significance.

On the basis of the experiments reported, disease has been such an important factor that it is impossible to distinguish the effect of immaturity as such.

EXPERIMENTAL METHODS

Most of the seed-potato production and comparative trial work was conducted at Lincoln. A small amount of seed stock was produced at Union (about 40 miles directly east of Lincoln) and at Bushnell and Alliance in the dry-land areas in western Nebraska. Culture was varied by growing some lots with and some without straw mulching and also with and without overhead irrigation. Straw mulches were generally applied at about the time the plants were ready to emerge from the soil. The straw covering was applied so as to provide a uniform mulch about 2 inches deep.

From 1921 to 1926 experimental lots of seed potatoes were planted and harvested on different dates at Lincoln. Early Ohio potatoes were used from 1921 to 1925. Irish Cobblers were added in 1925 and used afterwards. Each year good seed stocks were procured from the north or west.

Potatoes produced by the various treatments previously enumerated were held in the same storage and were planted in comparative plats the following year. These comparative trial plats were used as a means of determining the seed value of the various lots of seed. Growing conditions in the comparative trial plats were as uniform as possible for all of the

lots. As the yield of tubers was sometimes very low with some of the treatments, it was not always possible to plant the desired number of replicated plats with each seed lot. Likewise the size of the tubers varied, thus introducing another error in the trials. These exceptions are given due consideration at the proper place in the bulletin.

Krantz (1922) and some other workers have shown that the mean representing four single-row plats three or four rods long is practically as dependable as the mean from more plats or larger plats and that when a mean is based on fewer plats the probable error increases rapidly, approximately in line with the theoretical application.

The trial plats at Lincoln were always planted during the first two weeks of April. At North Platte the comparative plantings were made the latter part of April and at Scottsbluff during the early part of June. Furrow irrigation was practiced at the two latter places. Prior to 1923 spindle-tuber was present and infected tubers were recognized as "run out" stock. Beginning with 1923, when it was first recognized as a virus disease, more or less isolation, roguing, and seed selection were used to eliminate it as far as possible from the seed lots planted in the seed-producing plats. Later, to prevent some of the spreading among the lots intended for comparative trials, the cutting knife was disinfected (Goss, 1926). In spite of these precautions spindle-tuber continued to be a more or less serious factor. No other disease was ever a factor of any consequence in the experiments reported in this paper.

Altho most of the special terms used were described in a previous paper (Werner, 1925), it will be well to consider them briefly in this bulletin.

Spindle-tuber coefficient describes both the relative extent and severity of the disease symptoms of the plant. The spindle-tuber symptoms of each plant are evaluated on the basis of 100 for the most severe type of symptoms and symptoms of lesser severity evaluated accordingly. The mean coefficient for the lot is the sum of these individual plant values divided by the total number of plants.

Tuber type index is used to describe the shape, color, number and depth of eyes, etc. The tubers of ideal type were given a value of 10 and those of most inferior type 1 or less. Generally values between 6 and 10 represent normal or healthy tubers and all values of 5 or less "spindle tubers." Values of 6 or 7 may indicate mild symptoms of spindle-tuber.

Maturity notes were taken at regular intervals in several experiments. They are based on observations, the worker assuming dead vines to be 100 per cent mature. Others were rated accordingly.

Grades followed were the standard U. S. grades, arrived at by means of a Boggs grader. "Spindle tubers" that did not go thru the top belt (1 15/16 inches) were generally weighed separately. They did not represent the total amount of spindle-tuber infection since the disease caused many small potatoes which dropped thru the belt. Therefore the figures for No. 1 size "spindle tubers" can be considered as absolutely safe minimum figures. Generally one person was responsible for picking out all the "spindle tubers" at grading time.

EFFECTS OF SEASON OF GROWTH AND CULTURAL METHODS ON CURRENT CROP

The various environmental conditions under which potatoes are grown may exhibit their effects in two different crops—on the current season's production and on the progeny of such a crop. The effects on the current season crop, so far as outward appearances are concerned, are mainly vegetative. In the following tables are given a few of such effects which were measurable. Likewise, this tabular information presents clearly the conditions under which seed tubers were produced and also gives a measure of the practicability of the experimental methods employed.

RATE OF PLANT EMERGENCE

Emergence was much more rapid during the current season with each succeeding planting, altho after the middle of

TABLE 1.—*Emergence rate, stand, and relative yield from Early Ohio potatoes planted on different dates at Lincoln during 1921, 1922, and 1923. (See Fig. 1.)*

Range of planting dates during the 3 years	Mean of results during three years		
	Days for emergence of half of the plants	Stand	Mean yield from each planting date compared with that from first planting
(1)	*Days* (2)	*Per cent* (3)	*Per cent* (4)
April 1-15	39	98.2	100.0
April 16-20	34	96.8	76.2
May 1-5	29	95.6	71.1
May 13-18	23	95.9	51.9
May 26-29	22	95.7	29.9
June 10-18	22	67.7	38.4
June 24-27	26	72.7	19.1
July 6-11	21	88.0	12.3
July 16-25	18	77.0	10.3

June it was sometimes retarded by heat or drought. (Table 1.)

Plants in straw-mulched blocks emerged more slowly than in the cultivated blocks, especially in the early part of the season. (Fig. 1.)

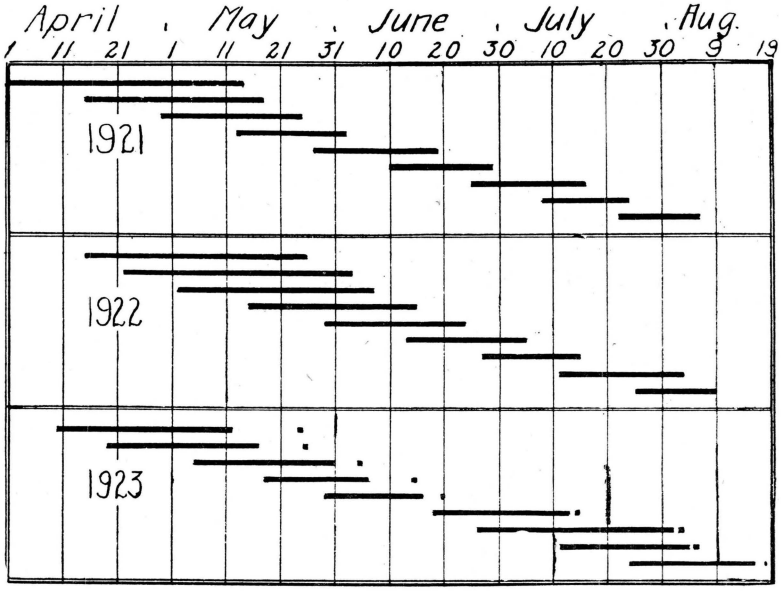

FIG. 1.—Number of days between planting date and date when 50 per cent of the plants of any one lot had emerged during each of three years at Lincoln with Early Ohio potatoes. In the 1923 portion the blocks to the right indicate the emergence date of the straw-mulched lots.

The earlier plantings almost uniformly produced the best stands, altho in this respect differences were slight until mid-June plantings. There was generally a decided decline in yield with each succeedingly later planting date.

GROWTH RATE OF PLANTS

Altho they required more time for emergence, the early plantings made the greatest growth. The growth rate for 1921 as measured by total height is graphically shown in Fig. 2. The early April plantings attained almost their maximum height by the middle of July. The late-planted lots grew more slowly than the earlier ones and never attained as great a height. The decided difference between the growth of May 13 and May 27 plantings is probably due to the hot weather during late June and early July when the May 27 lots were just getting established.

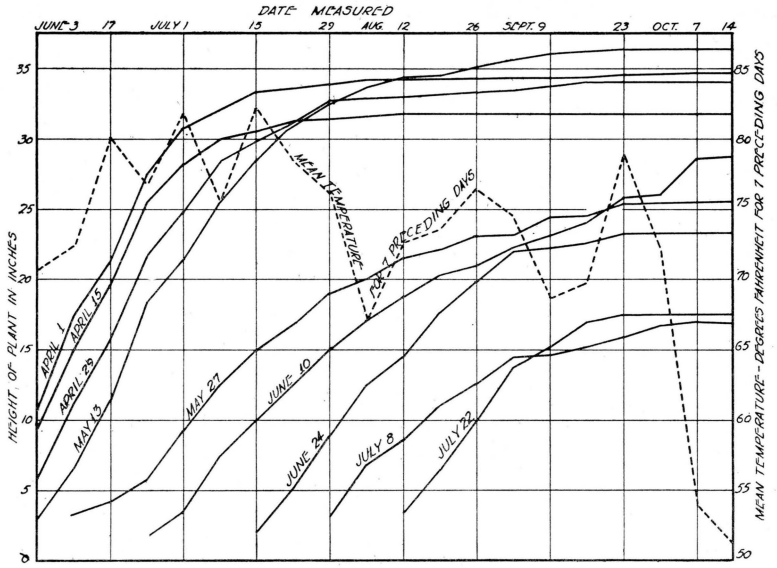

FIG. 2.—Rate of plant growth of Early Ohio potatoes planted at Lincoln on different dates in 1921. (All plants thinned to single stems.)

TIME OF VINE MATURITY

It has been shown (Clark, 1921) that the period of greatest tuber enlargement occurs shortly before the time of plant maturity. Unpublished work by the author indicates that under early-crop conditions in eastern Nebraska, tubers are formed very early in the life of the plant but that their maximum growth occurs just after the plants have attained maximum size and before they show signs of maturity. In 1921 the early-planted lots were practically mature by mid-August, having made most of the tuber development in the hot weather of July. (Table 2.) The June and later plantings did not mature until October or even not at all. Thus their tubers were developed in the cooler weather of September.

Rosa (1928) has shown that the time of maturity is of further importance in connection with its relation to the rest period. The early-maturing stocks, or stocks which are most mature at harvest time, will complete their rest periods earlier during the storage period with consequent earlier sprouting.

YIELD OF TUBERS

Mulching with straw is generally a good means of increasing the yield of tubers. (Fig. 3.) In only one season between

TABLE 2.—*Rate of vine maturation of Early Ohio lots planted in 1921 at Lincoln on different dates*

Date of observation	Dates planted								
	Apr. 1	Apr. 15	Apr. 29	May 13	May 27	June 10	June 24	July 8	July 22
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Percentage of vine maturity								
June 24	0								
July 7	28	6	0						
July 22	60	50	38						
Aug. 5	70	60	45	20					
Aug. 19	95	95	80	50	50				
Aug. 26	100	96	95	93	70				
Sept. 2	100	100	100	100	95	30			
Sept. 16	100	100	100	100	99	67	30		
Sept. 18	100	100	100	100	100	70	37		
Sept. 30	100	100	100	100	100	80	40	35	
Oct. 14	100	100	100	100	100	100	50	50	30

1922 and 1926 did the cultivated plat outyield the straw-mulched plat. The season of 1923 was cool and wet, unlikely to result in increased yields from straw mulching.

Thruout the three years when potatoes were planted at short intervals, the yields from the first or second plantings were almost invariably the greatest, with lower yields from May and very low yields from June and July plantings. (Fig. 4.) There was considerable variation in this respect from year to year due to seasonal differences.

From the economic standpoint, it is important to know not only when the crop matures but also the time beyond which not much tuber growth takes place. With early April plantings (Fig. 5) it appears that from 25 per cent to 75 per cent of the final crop had developed by the middle of July. However, due to great seasonal variation it seems inadvisable to expect more than 25 per cent of the total crop by that date with cultivation, and still less with straw mulching. By the middle of August, 75 per cent or more of the total crop yield was produced each year.

Straw mulching and irrigation increased the yields. Irrigation was of more value in cultivated than in straw-mulched plats. (Fig. 6.) Straw mulching was of more value with early plantings, while irrigation gave greater relative increases with later plantings.

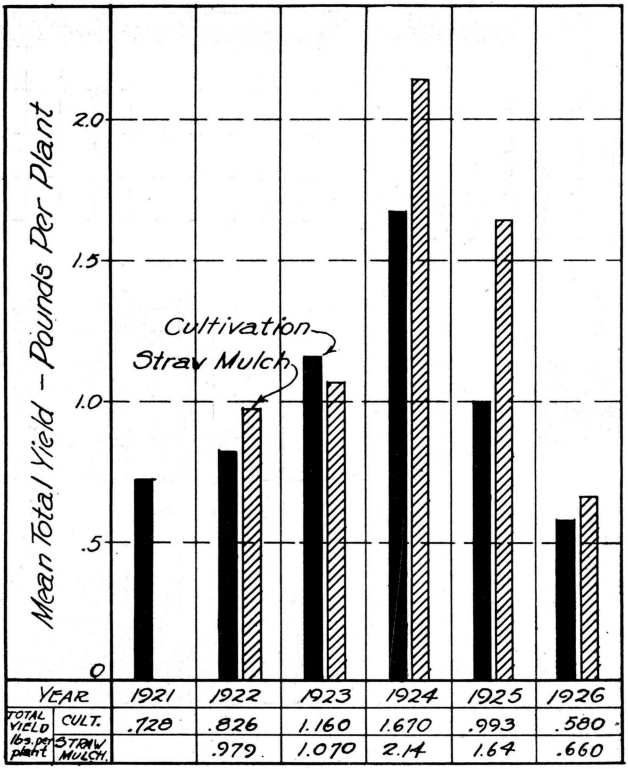

FIG. 3.—Mean yield per plant in cultivated and straw-mulched plats at Lincoln—1921 to 1926—when planted early and harvested late each season.

COMPOSITION OF TUBERS

Chemical analyses [1] of tubers harvested just before vines were ripe in August, 1925, revealed less dry matter, protein, sugar, and starch than those of tubers harvested in October. Straw-mulched potatoes were higher in dry matter and starch but lower in protein and sugar than the cultivated stocks. Irrigated potatoes were lower in dry matter, protein, sugar, and starch than non-irrigated tubers. (See Table 3.)

SPINDLE-TUBER PREVALENCE IN RELATION TO YIELD AND GRADE

It has been shown (Werner, 1924) that high temperatures and a long growing season are favorable for bringing out the

[1] Chemical analyses were made by the Department of Agricultural Chemistry under the supervision of Dr. M. J. Blish.

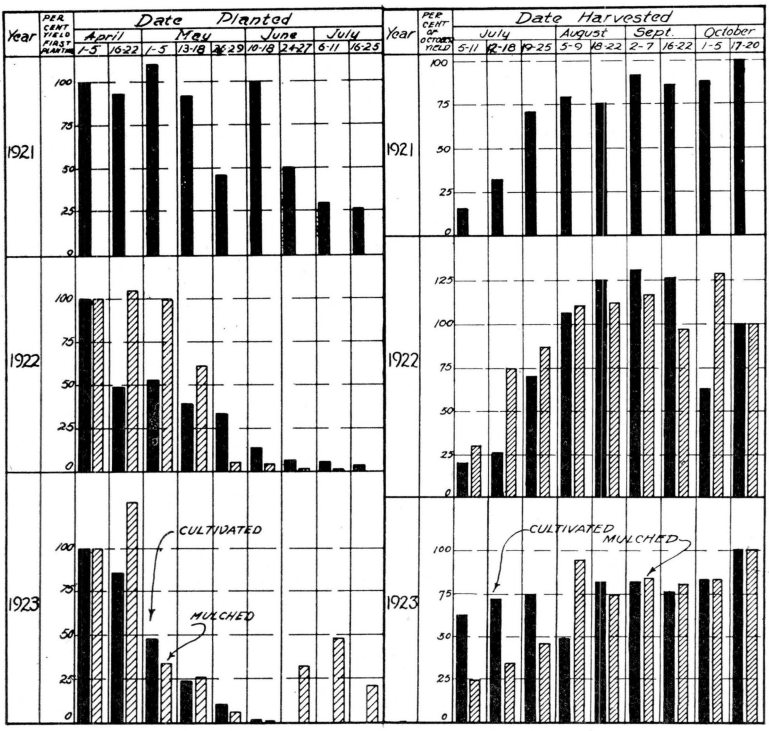

FIG. 4.—(Left.) Relation of date of planting to yield at Lincoln during seasons of 1921, 1922, and 1923. All lots were harvested in October. Yield for each planting date is shown as percentage of the yield from the first April planting. Cultivated lots are comparable only with cultivated lots of the same year and mulched lots only with mulched lots.

FIG. 5.—(Right.) Yields from harvesting on various dates compared with that from October harvesting. All lots were planted at Lincoln during the early part of April each year. Fluctuations are the result of an insufficient number of plats of each lot.

symptoms of spindle-tuber in contrast with healthy plants. On the basis of plant-top symptoms, on June 30, 1923, the April 10 plantings showed a mean spindle-tuber coefficient of 9.43 in the cultivated plats as compared to 3.0 in the mulched plats. In the May 18 plantings the coefficients were 8.93 and 1.67 respectively. These readings may indicate either difference in time of infection or in the rate of spread of the virus within the plant, more extensive transmission in the cultivated plat, or possibly merely different degrees of symptom masking.

When potatoes were harvested the "spindle tubers" that did

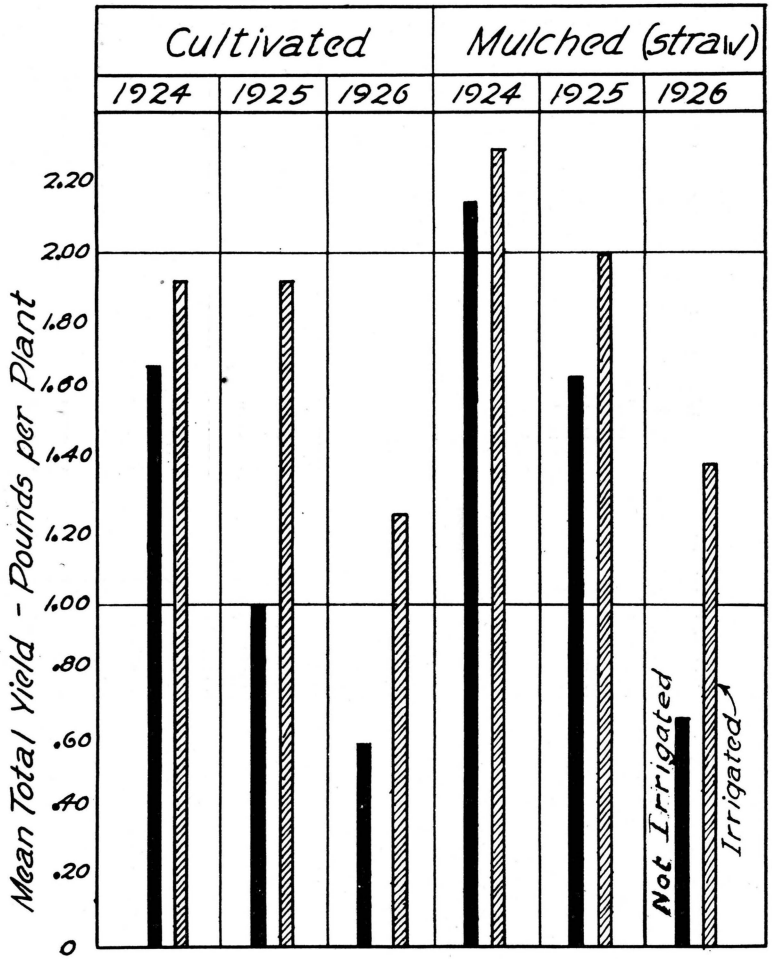

FIG. 6.—Yield in irrigated and non-irrigated plats with and without straw mulches, during three years at Lincoln.

not go thru the top chain (1 15/16 inches) of the grader were picked out and weighed separately. As a measure of the disease prevalence such classification is of course subject to several errors—in the judgment of the person picking out the "spindle tubers," from uncertainty in case of questionable tubers, and from the fact that many spindle tubers will be smaller and fall thru the screen. In the latter event one would expect severely infected lots to show a higher percent-

TABLE 3.—*Composition of Irish Cobbler potatoes grown at Lincoln in 1925 (basis of fresh tuber weights)*

Culture	Dry matter	Protein (Nx625)	Total sugar	Starch
	Per cent	*Per cent*	*Per cent*	*Per cent*
Tubers harvested August 20				
Cultivation—Unirrigated	15.5	1.72	0.117	10.60
Irrigated	14.6	1.61	0.276	9.78
Straw mulch—Unirrigated	16.8	1.73	0.628*	11.45
Irrigated	15.4	1.39	0.199	10.85
Tubers harvested October 10				
Cultivation—Unirrigated	18.3	3.11	0.520	10.9
Irrigated	16.8	2.20	0.284	10.7
Straw mulch—Unirrigated	20.2	2.55	0.348	14.1
Irrigated	18.7	1.77	0.263	13.0

* The reason for this inconsistency is not understood.

age of No. 2 and cull-size potatoes. Such is the case as shown graphically in Fig. 7. In case of very severely infected lots the percentage of No. 1 size "spindle tubers" may be less, but the total percentage of No. 2 and cull-size tubers may be much greater than in the less severely infected lots. Hence the total of these three grades or, reversely stated, the percentage of No. 1 prime (not "spindle tubers") may be the best index of spindle-tuber infection. This is especially the case with lots seriously infected with unmottled curly dwarf. For the purposes of this paper no effort is made to differentiate with regard to these two diseases.

EFFECT OF SEASON OF GROWTH AND CULTURAL METHODS UPON SEED VALUE OF POTATOES AS SHOWN BY THE SUCCEEDING CROP

The seed potatoes produced by the various treatments were grown in comparative plats, the following year, to determine whether these treatments were of any significance beyond the current season—that is, whether they altered the seed value of the tubers in any way. Because of the difference in treatments, conditions, etc., the results secured from plantings at Lincoln and Union are reported separately. The experiments are also divided, as much as possible, on the basis of the presence or absence of spindle-tuber in the seed stocks.

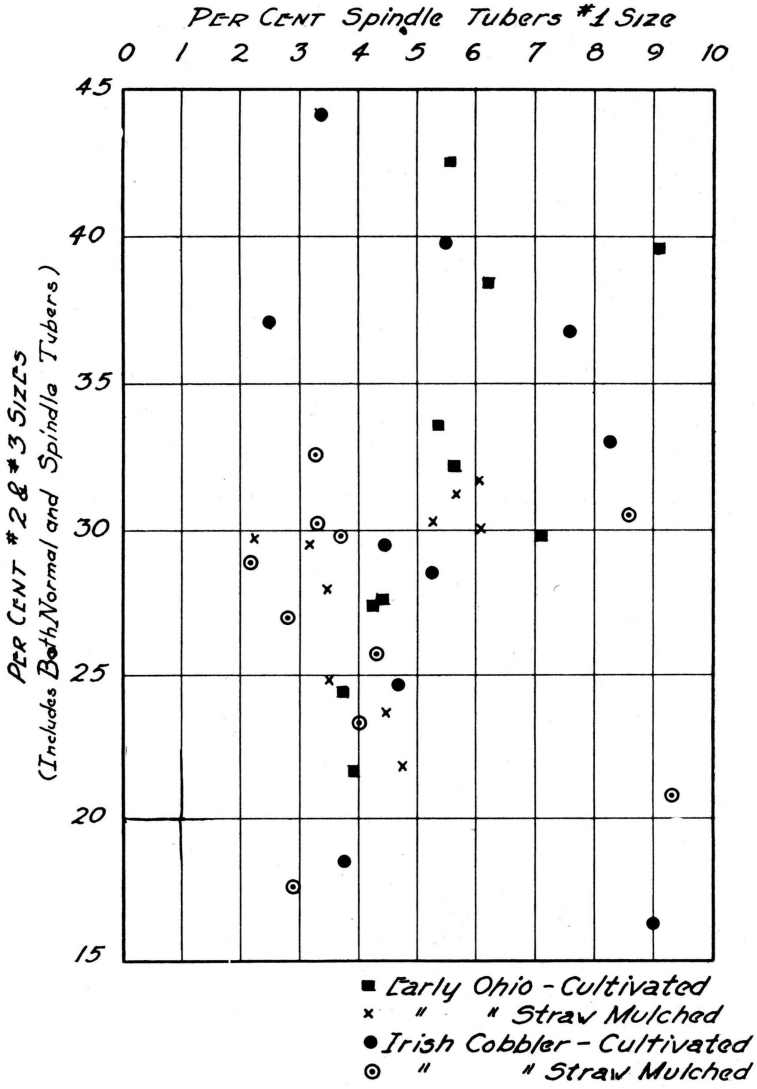

FIG. 7.—Showing relation between percentage of small tubers and spindle-tuber content. Data based on 1925 trial lots grown at Lincoln. Culture and variety are indicated by distinctive signs.

SEED POTATOES PRODUCED AT LINCOLN[2]

When studying the yield data from the comparative plats

[2] During most of the seasons when the Lincoln work was conducted, spindle-tuber was a factor of considerable consequence. The data procured during the earlier and later years are therefore presented separately, because of the difference in spindle-tuber content.

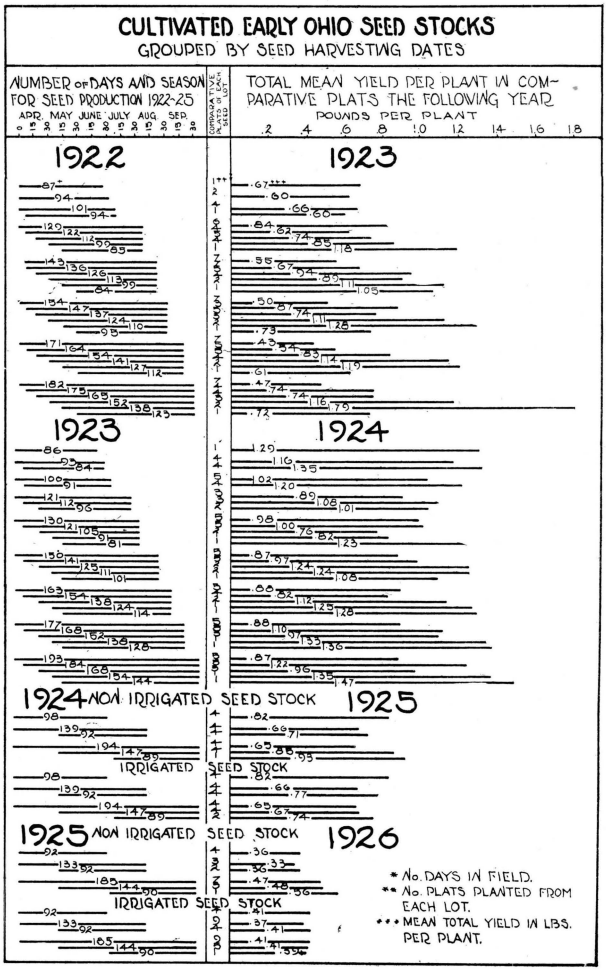

FIG. 8.—Yields in comparative plats from Early Ohio seed potatoes produced at Lincoln during varying seasonal periods in cultivated seed plats. Data presented by harvesting date groups. Irish Cobbler used during the last two years performed in a similar manner. New lots of seed were planted in the seed plats each year and handled according to the given conditions. One-row plats in comparative trials consisted of 25 hills each in 1923, 40 hills in 1924, 75 in 1925, and 40 in 1926.

it is important to keep in mind that the number of plats was not the same in all cases, due to the low yields from some treatments in the seed producing years. Unless otherwise

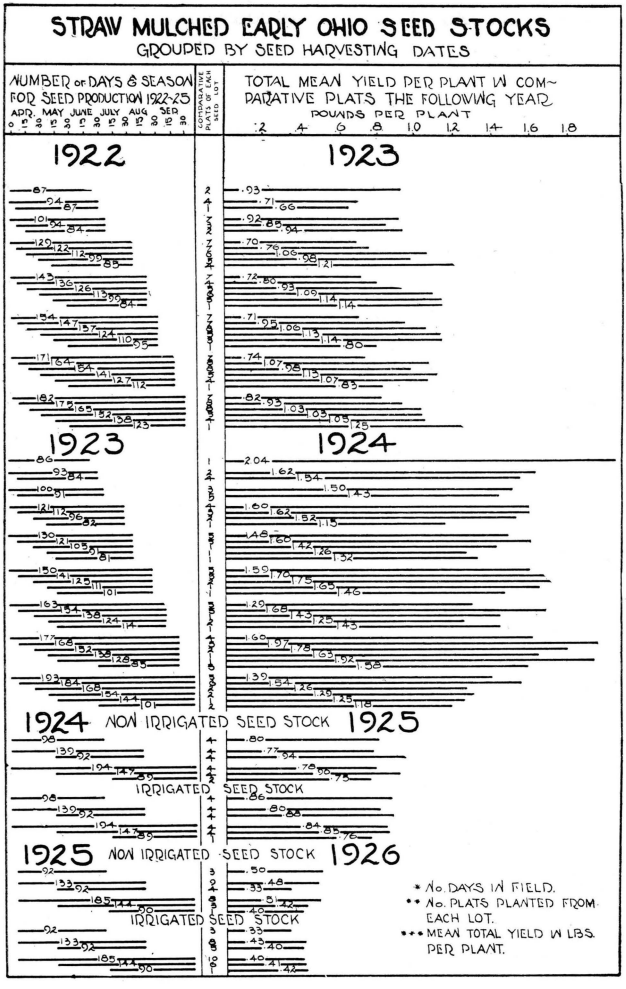

FIG. 9.—Yields in comparative plats from Early Ohio seed potatoes produced at Lincoln during varying seasonal periods in straw-mulched seed plats. Data are presented by harvesting-date groups. Irish Cobbler used during the last two years performed in a similar manner. New lots of seed were planted in the seed plats each year and handled according to the given conditions. (For size of plats see Fig. 8.) Asterisks have same application as in Fig. 8.

stated, all data reported were secured with the Early Ohio variety. Data are not given for all of the years because of the space necessary to print them.

Seed stocks infected with spindle-tuber. — Altho the

original seed stocks were produced in commercial fields of supposedly good, healthy stock, some of these stocks produced distinctly spindle-tuber plants. The presence of this infection was a serious factor thruout the experiment. The increase in spindle-tuber from year to year was distinctly influenced by the different treatments used in producing the seed potatoes.

Planting-time effect.—When considering the potatoes harvested on any one date, the least productive lots the following year were generally those planted early, that is, in early April. (See Figs. 8, 9, and 10.) This was especially the case with the cultivated lots and the straw-mulched lots of 1922-23. Frequently, however, the seed stocks raised from mid-June plantings were less productive than the May-planted stocks but even so were still more productive than the April-planted lots. This may have been due to more incomplete development of the buds within the eyes (Rosa, 1928) in the tubers from June plantings. With June planting at Lincoln the tuber production was relatively later than with April or May plantings and the tubers produced were very small. Frequently it was impossible, even by planting whole tubers, to have seed pieces from the June lots that weighed as much as the standard seed weight for the April and May lots. Hence, with the June lots, allowance must be made for the slightly smaller seed pieces, the greater number of eyes per seed piece, and the relatively more incomplete development of the buds. Since straw mulching delayed early growth, all mulched tubers were more immature than the cultivated tubers with the same seasonal dates.

Spindle-tuber was responsible for much of the lower yield of the April lots. It was also responsible for the greater variation in the early years. This phase is discussed more completely on pages 16 and 17.

The relative productivity of seed potatoes from different planting dates was influenced by the harvesting date. This aspect is dealt with when consideration is given to the length of time parent plants were in the field. (See pages 24 and 25.)

The low yields secured by late planting the year when the seed is produced, raise the question of the practicability of planting late for seed production. (See Fig. 4.)

Harvest-time effect.—When considering potatoes planted on any one date, the lots harvested early were generally the most productive the next year. This condition prevailed practically always with April-planted cultivated stocks. It was not so generally true with May and June plantings, or with the straw-mulched seed stocks. (See Table 4 and Fig. 10.) Early harvesting was less effective in increasing yields

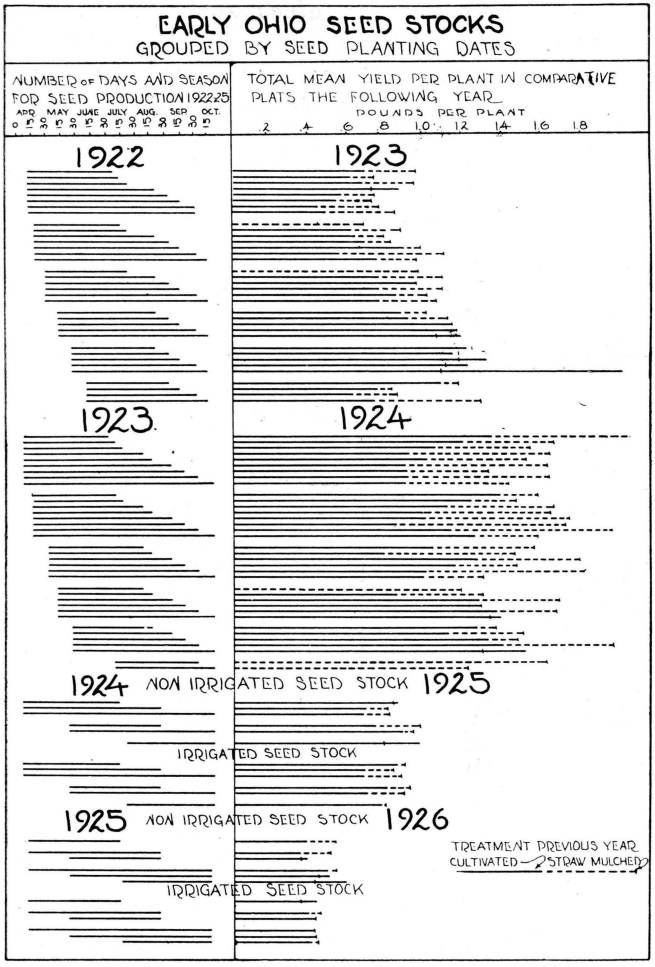

FIG. 10.—Yields in comparative plats from Early Ohio seed potatoes produced at Lincoln during varying seasonal periods in cultivated and straw-mulched seed plats. Data are presented by planting-date groups. Irish Cobblers used during the last two years performed in a similar manner. New lots of seed were planted in the seed plats each year and handled according to the given conditions. (For size of plats see Fig. 8.)

the next year than was late planting. The longer tuber storage season was probably one factor accounting for this difference.

Early harvesting prevented some spindle-tuber infection

TABLE 4.—*Yields from seed potatoes harvested during various months reported as percentages of the yield from October-harvested lots. All lots compared were planted on the same dates and given the same culture the previous year*

Approximate planting time previous year	Year of comparative trials	Culture given seed stock previous year, and month when seed stock was harvested							
		Cultivation				Straw mulch			
		July	Aug.	Sept.	Oct.	July	Aug.	Sept.	Oct.
(1)	(2)	*P. ct.* (3)	*P. ct.* (4)	*P. ct.* (5)	*P. ct.* (6)	*P. ct.* (7)	*P. ct.* (8)	*P. ct.* (9)	*P. ct.* (10)
Early April	1923	143	116	116	100	111	115	92	100
	1924	126	109	100	100	119	111	105	100
	1925		99		100		99		100
	1926		82		100		96		100
Early May	1923	110	104	106	100	93	109	101	100
	1924		79	104	100		97	94	100
Late May	1923		106	106	100		115	108	100
	1924			83	100				
	1925		80		100		91		100
	1926		79		100		74		100
Middle June	1923			129	100			139	100

but it was less effective in this respect than late planting. In 1923 and 1924 this disease was a limiting factor. In the 1925 and 1926 trials when spindle-tuber was a minor factor, the yield differences were much smaller.

Effect of the length and season of the crop period.—The total yield data from the comparative plats of 1923 are grouped in Table 5, according to the approximate number of days from planting till harvest time during 1922 when the seed tubers were produced. Within a group representing approximately the same number of days the several lots are arranged in planting-time sequence. Due to slower emergence in early spring (Fig. 1), the plants of the earlier planted lots of a group were not actually above the soil as long as the later planted lots.

TABLE 5.—*Total yield from various lots of seed potatoes arranged by the number of days and seasons that the parent plants were in the field at Lincoln*

Treatment in 1922				Mean pounds per plant in comparative trials—1923	
No. of days from planting to harvesting	No. of days 50% or more plants were above ground	Planting date	Harvesting date	Seed produced in cultivated plat in 1922	Seed produced in straw-mulched plat in 1922
(1)	(2)	(3)	(4)	(5)	(6)
87	46	April 16	July 11	.67 (1)*	.93 (2)*
84	42	April 22	July 18	.....	.66 (1)
84	48	May 2	July 25	.....	.94 (2)
85	59	May 29	Aug. 22	1.18 (1)	1.21 (4)
84	62	June 13	Sept. 5	1.05 (1)	1.14 (1)
94	53	April 16	July 18	.60 (2)	.71 (4)
94	52	April 22	July 25	.60 (1)	.85 (3)
95	73	June 13	Sept. 16	.73 (1)	.80 (1)
101	60	April 16	July 25	.66 (4)	.92 (7)
99	68	May 15	Aug. 22	.85 (4)	.98 (5)
99	73	May 29	Sept. 5	1.11 (2)	1.14 (3)
112	76	May 2	Aug. 22	.74 (5)	1.06 (6)
113	82	May 15	Sept. 5	.89 (4)	1.09 (6)
110	84	May 29	Sept. 16	1.28 (2)	1.14 (3)
112	90	June 13	Oct. 3	.61 (1)	.83 (1)
122	80	April 22	Aug. 22	.62 (4)	.76 (7)
126	90	May 2	Sept. 5	.94 (5)	.93 (5)
124	93	May 15	Sept. 16	1.11 (3)	1.13 (5)
127	101	May 29	Oct. 3	1.19 (2)	1.07 (4)
123	101	June 13	Oct. 14	.72 (1)	1.25 (1)
129	88	April 16	Aug. 22	.84 (6)	.70 (7)
136	94	April 22	Sept. 5	.67 (7)	.80 (4)
137	101	May 2	Sept. 16	.74 (5)	1.06 (8)
141	110	May 15	Oct. 3	1.14 (4)	1.13 (5)
138	112	May 29	Oct. 14	1.79 (2)	1.05 (4)
143	102	April 16	Sept. 5	.55 (7)	.72 (7)
147	105	April 22	Sept. 15	.87 (3)	.95 (7)
154	113	April 16	Sept. 16	.50 (7)	.71 (7)
154	118	May 2	Oct. 3	.83 (5)	.98 (8)
152	121	May 15	Oct. 14	1.16 (3)	1.03 (5)
164	122	April 22	Oct. 3	.54 (5)	1.07 (8)
165	129	May 2	Oct. 14	.74 (4)	1.03 (8)
171	130	April 16	Oct. 3	.43 (7)	.74 (7)
175	133	April 22	Oct. 14	.74 (4)	.93 (8)
182	141	April 16	Oct. 14	.47 (7)	.82 (7)

* Parenthetical numbers in Columns 5 and 6 refer to number of 25-hill plats planted with each lot of seed.

Altho with the lot planted April 16 and harvested July 11 there were 87 days between planting and harvesting time, there were only 46 days (Table 5, Column 2) during which 50 per cent or more of the plants were above the ground—counting from the time 50 per cent of the plants emerged (Fig. 1) until harvest. In contrast with this was the lot planted June 13 and harvested September 5, thus occupying the land 84 days but with 50 per cent or more of the plants above ground for 62 days. In most of the season length-groups, the plants of the early-planted lots were above the ground between 7 and 21 days less than the late-planted lots of the group. These circumstances should be kept in mind when studying Table 5. As the length of time the actual seed-producing plants were in the field cannot be definitely stated (individual plant records not having been kept) the time between planting and harvesting is considered the most advisable basis for tabulating results.

With both cultivated and straw-mulched stocks the seed from the latest planted lot of each length group generally outyielded that from the earliest planted lot of the same group. The several exceptions, wherein the later-planted lots were low yielding, are based on less reliable data due to the smaller number of plats.

Untabulated 1923-1924 data do not reveal such distinct differences or tendencies, especially with the shorter length groups. (See Figs. 8, 9, and 10.) In the groups representing 121 days or more the later-planted cultivated lots were commonly the most productive.

Apparently when the number of days in the field was approximately the same, seed stocks planted late and harvested late the previous year were more desirable than those planted early and harvested early. These tendencies were less pronounced when seed stocks were practically disease free than when spindle-tuber was present.

Effect of straw mulching.—Thruout the 4 years of the comparative trials, the mulched seed stocks outyielded the cultivated seed stocks in practically every instance. These data summarized in Table 6 are graphically presented in Figs. 8, 9, and 10. It will be noted that seed potatoes produced under a straw mulch did not profit as much by either late planting or early harvesting as did cultivated stocks. However, with the lots harvested latest there was somewhat more improvement from straw mulching than with the earliest-harvested lots. Straw mulching was much more beneficial to early-planted seed stocks than to late-planted stocks. Straw-mulched stocks produced a lower percentage of tubers showing spindle-tuber symptoms than did the cultivated stocks. Mulching seemed to be less favorable for disease spread.

TABLE 6.—*Yield from straw-mulched seed potatoes reported as percentage of the yield of cultivated seed stock. The lots of seed compared were planted and harvested on the same date*

Approximate planting time previous year	Year of comparative trials	Month seed stock was harvested the previous year				Mean of lots harvested in Aug. and Oct.
		July	Aug.	Sept.	Oct.	
(1)	(2)	*P. ct.* (3)	*P. ct.* (4)	*P. ct.* (5)	*P. ct.* (6)	*P. ct.* (7)
Early April	1923	133.7	140.1	136.4	172.2	156.1
	1924	148.0	160.2	165.0	155.8	158.0
	1925	98.3	118.7	*	112.9	115.8
	1926	114.1	131.9	*	111.1	121.5
Mean of 4 years		123.3	137.7	*	138.0	137.9
Early May	1923	*	135.5	112.2	128.8	132.2
	1924	*	165.2	120.1	130.4	147.8
Late May	1923	*	103.1	96.0	93.9	98.5
	1924	*	105.1	122.8	118.4	111.8
	1925	*	110.6	*	111.4	111.0
	1926	*	100.5	*	109.9	105.2
Mean of 4 years		*	104.8	*	108.4	106.6

* Comparable lots were not available where data are omitted.

This fact possibly explains the superior yields of the straw-mulched stocks. Straw mulching seems to have manifested much greater influence on yields than any of the other manipulations employed.

Rejuvenation of Early Ohio seed stocks at Lincoln by straw mulching was reported by Emerson (1914). In 1925 potatoes which had been grown at Lincoln since 1923 and which contained many "run out" tubers, "spindle tubers," were planted at Lincoln under ordinary cultivation conditions and under a straw mulch. In the 1926 trials the yields from the cultivated and straw-mulched seed stocks were respectivelly 0.129 pound and 0.117 pound per plant. Of this crop "spindle tubers" and culls comprised 41.6 per cent of the crop from the cultivated seed and 42.7 per cent from the straw-mulched seed. In this stock—in which spindle-tuber infection was general—straw mulching did not rejuvenate the seed stock nor did it reduce the amount of spindle-tuber.

Effect of irrigation.—Altho irrigation caused a decided increase in yield during the year when the seed tubers were produced (Fig. 6), it had relatively little effect upon the productiveness of such seed potatoes the following season. The differences occuring were hardly significant, for among 24 comparable pairs of treatments there were 9 in which the irrigated stocks were superior. (Data presented in Figs. 8, 9, and 10 are for Early Ohios while those in Table 7 are based on both Ohios and Cobblers.) Combinations of other cultural conditions such as mulching, planting time, and harvesting time with irrigation, did not seem to be of any special significance.

In considering these data it is well to note that the stocks used for this phase of the experiment were relatively free from spindle-tuber.

TABLE 7.—*Yield in 1925 and 1926 from Early Ohio and Irish Cobbler irrigated seed potatoes reported as percentage of the yield of non-irrigated seed stock. The seed lots compared were planted and harvested on the same dates and were given the same culture*

Dates in years when seed was produced		Culture given seed potatoes the previous year				Mean of both treatments both years
		Straw mulched		Cultivated		
Planting	Harvesting	1925	1926	1925	1926	
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Early April	July 16	113.9	86.0	97.0	92.0	97.2
	Aug. 26	88.9	93.4	94.2	98.7	93.8
	Oct. 17	108.0	88.9	100.1	93.4	97.6
Mean of Aug. & Oct.		98.5	91.2	97.7	96.1	95.7
Late May						
	Aug. 26	106.3	122.4	109.4	107.8	111.5
	Oct. 17	90.5	93.2	88.0	86.1	89.5
Mean of Aug. & Oct.		97.8	105.7	97.5	95.7	99.2
Mid-July	Oct. 17		101.2		101.3	
Mean for April and May lots harvested in Aug. and Oct.		97.7	95.9	97.3	95.8	96.7

Relation of cultural practices to spindle-tuber.—The relation of time-of-planting and culture to the development and spread of spindle-tuber has been referred to previously (Werner, 1925). Additional data upon this question have been procured.

On June 30, 1923, Early Ohio plants in the comparative plats (produced from seed planted in early April but harvested on different dates from cultivated and mulched plats

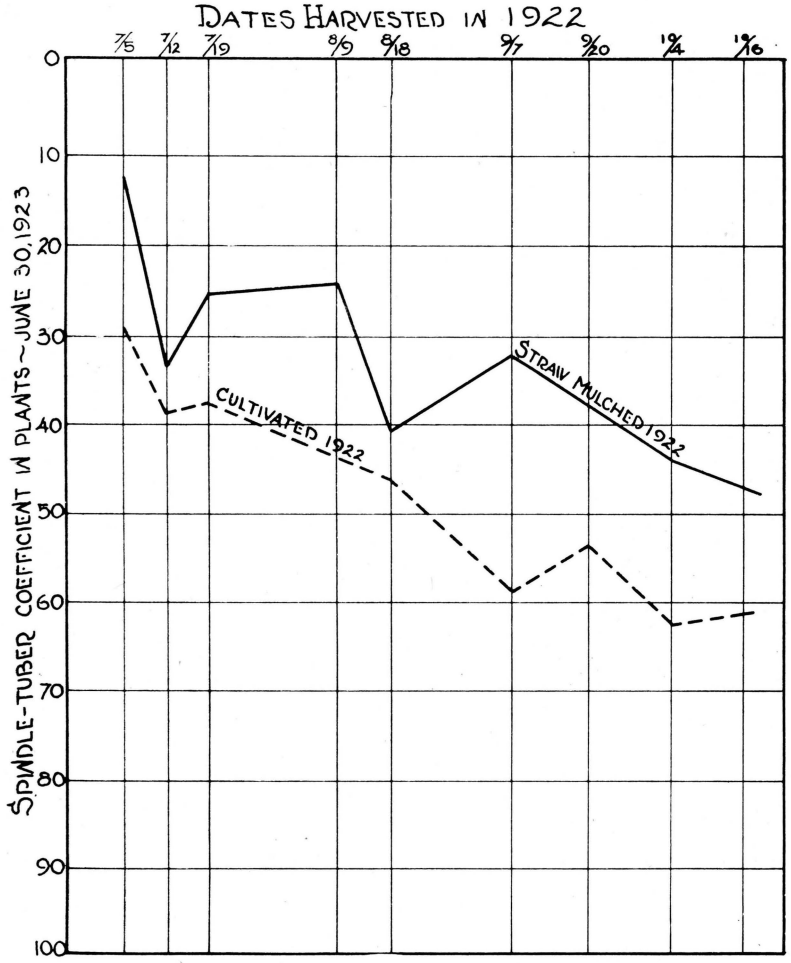

FIG. 11.—Mean spindle-tuber coefficient of plants in 1923 comparative plats grown from seed lots harvested on different dates from straw-mulched and cultivated plats at Lincoln in 1922.

in 1922) were classified with regard to the degree of spindle-tuber infection. The mean spindle-tuber coefficients for the plants from seed stocks thus grown are shown in Fig. 11. These indicate that the severity of infection increased quite uniformly as the seed stock was harvested on a succeedingly later date. They also show that in every case the tubers produced by cultivated seed stocks had a higher spindle-tuber coefficient than comparable straw-mulched stocks.

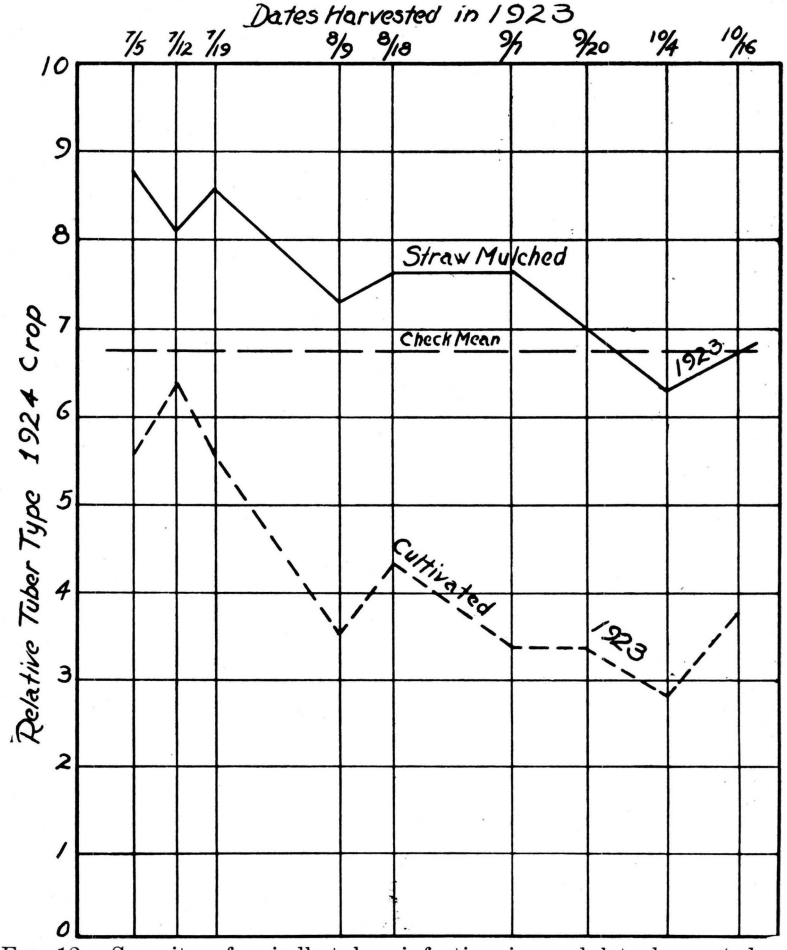

FIG. 12.—Severity of spindle-tuber infection in seed lots harvested on different dates in 1923 from straw-mulched and cultivated plats at Lincoln as measured by mean relative tuber type of crop produced in comparative trials at Lincoln in 1924.

In 1924 the tubers harvested from lots comparable to those used in 1923 were classified with regard to tuber type (see page 10 for method) instead of according to the spindle-tuber coefficients of the plants, and a mean established for each lot. The tuber type generally decreased as the seed stock was harvested on each successively later date. (Fig. 12.) The cultivated stock produced tubers with a lower tuber type index value than did comparable mulched stock.

A detailed analysis of some of the 1924 data (Fig. 13) shows that the low tuber type of the cultivated stock was due to the presence of a large number of potatoes of the poorest type, whereas the mulched stock produced a large number of tubers of the very best type. The 1923 July-harvested lots, both mulched and cultivated, tended to produce many more good-type tubers than the October-harvested stocks. The July-harvested mulched stock produced practically no tubers of the poorest type as contrasted with the other extreme of practically no tubers of the best type from the October-harvested cultivated stock. These lots which produced poor-type tubers were also the least productive. The yields of all these lots are reported in Figs. 8, 9, and 10.

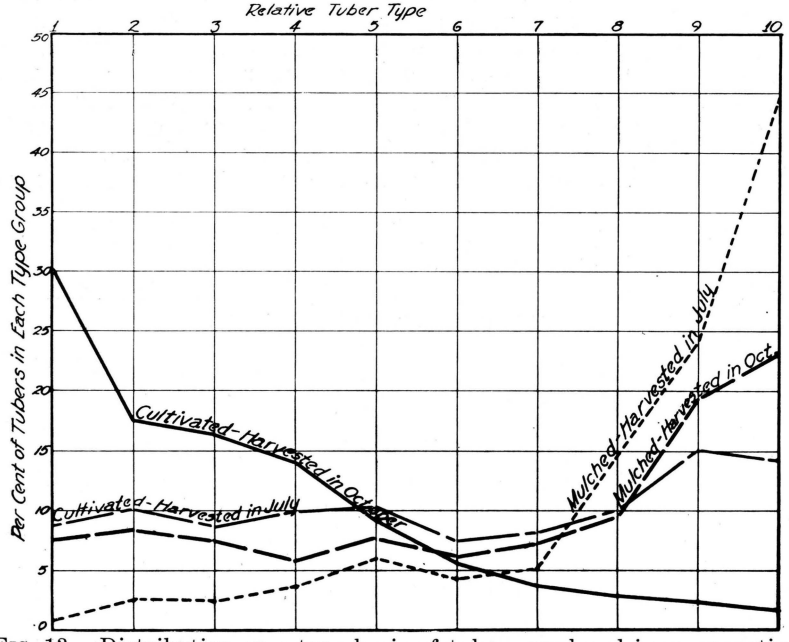

FIG. 13.—Distribution on a type basis of tubers produced in comparative plats. Both mulched and cultivated seed plats were planted in April, 1923, and harvested as indicated.

In the season of 1925 all tubers were graded at harvesting time and the No. 1 size "spindle tubers" were weighed separately. The data for these weights are shown graphically in Fig. 14. Spindle-tuber was less severe in the lines of seed used that year than in those of previous seasons. Cultivated seed stock tended to produce more "spindle tubers" than the mulched-seed stock. April-planted seed stock harvested in October produced more "spindle tubers" than that harvested in August or July. The spindle-tuber percentage from stock planted May 26 was not appreciably altered by time of harvesting. There was no tangible difference between irrigated and non-irrigated seed stock. Evidence presented elsewhere (page 16) indicates thae these estimates of spindle-tuber are relatively low (Fig. 7), probably because many tubers were small due to the disease.

In any replicated lot, the higher-yielding sets showed only a low percentage of "spindle tubers." These, together with the other data, suggest that low yields as well as poor tuber type were associated with the presence of spindle-tuber.

Effect of cultural practices on grade of tubers.—Late-harvested seed stocks from May plantings generally produced a higher percentage of No. 1 prime tubers than the early-harvested stocks, but in the case of April plantings early-harvested stocks gave the more desired results. There was a greater variation with the Irish Cobbler than with the Early Ohio. (Fig. 14.) Thruout all the years the mulched stocks produced a decidedly higher percentage of prime tubers than comparable cultivated stocks, altho in 1925 this difference was less marked.

Late-planted stocks were slightly superior in the production of primes to those planted early. Irrigation of seed stocks apparently had even less effect than the other cultural practices upon tuber grade the following year.

The correlation between the percentage of "knobby" and "growth cracked" Early Ohio tubers and cultural practices used in seed production is graphically shown in Fig. 14. The lower percentage of No. 1-size "spindle tubers" in these same lots suggests that their plants were better able to withstand the unfavorable summer weather. (Note yields for these lots in Figs. 8, 9, and 10.) This permitted them to renew growth later in the season with consequent production of knobby tubers, whereas plants with considerable spindle-tuber never survived the summer and of course produced fewer or no second-growth tubers. The Early Ohio check lots, planted with new seed from Minnesota, produced more knobby and cracked potatoes than any of the Lincoln-grown

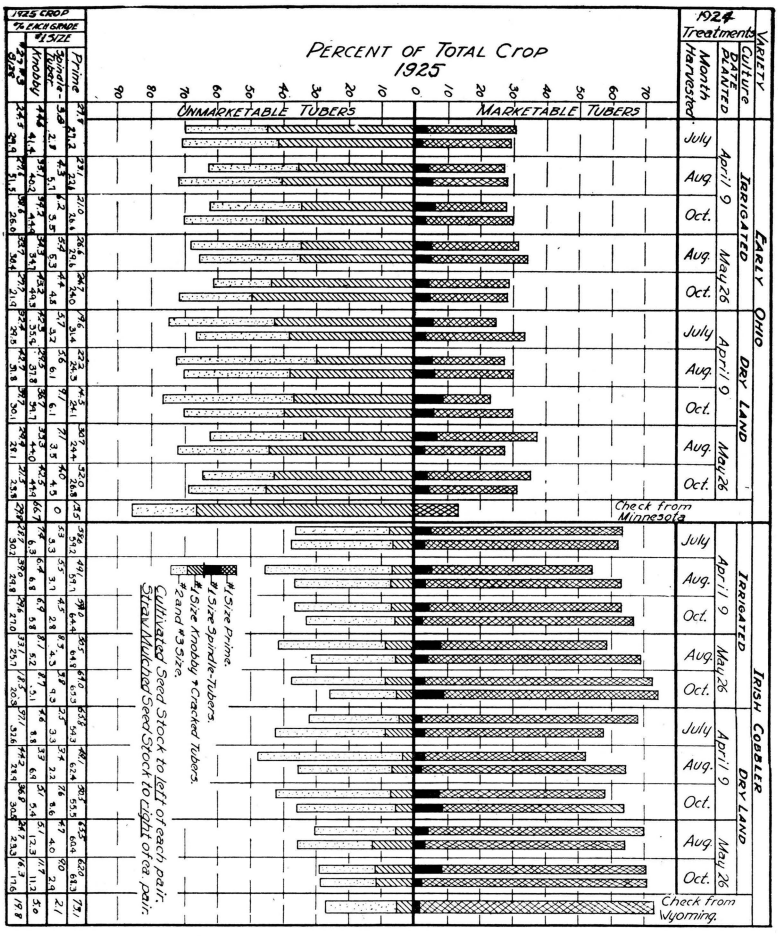

FIG. 14.—Grade of tubers of two varieties produced in 1925 from seed potatoes which had been grown under different cultural conditions and which were planted and harvested on different dates at Lincoln in 1924.

lots. The Early Ohio variety lots always produced more knobby tubers than the Irish Cobbler lots.

A higher percentage of No. 2 and No. 3 sized tubers was generally produced by the mulched than by the cultivated seed stocks. (Fig. 14.) Likewise, early-planted stock generally produced a higher percentage of small tubers than comparable early-planted stock. Time-of-harvesting and also irrigation seemed to have had less consistent effect in this regard.

The higher percentage of small tubers in cultivated and early-planted stocks may have been due to the tubers having started on and emerged from their rest period at an earlier date and consequently having lost some degree of apical dominance, with a consequent heavier set of tubers which remained small due to moisture shortage. Differences in apical dominance at the time of planting the trial plats and spindle-tuber content of seed stocks probably explain the differences observed.

Healthy seed stocks produced in isolated plats.—In 1926 Irish Cobbler potatoes from western Nebraska were planted in an isolated field at Lincoln at monthly intervals, from the middle of April to the middle of July, and all were harvested in October. In April, 1927, twelve 40-hill, single-row plats from each lot were planted (magic square distribution) on the same farm. At this time the early-planted lots showed the most sprout growth. Minnesota-grown Cobblers were inserted as checks in every tenth plat.

Effect of time of planting.—The early-planted lots showed the earliest signs of maturity, followed in regular order by the lots from the succeeding dates. (Table 8.)

The April- and May-planted stocks were less productive than the later-planted ones. (Table 9.) The percentage of No. 1 tubers increased with each succeedingly later planted lot. This difference is probably of more significance than the differences in total yield. June- and July-planted stocks were as productive as the checks.

These differences in favor of the earlier-planted stocks are believed to be due to their earlier arrival at the tuber-production stage because of their greater advancement at planting time in 1927.

Because of the tubers from the early-planted seed lines being less dormant at planting time, apical dominance was less pronounced (Appleman, 1924) and consequently more stems were produced per seed-piece with a consequent reduction in the size of the individual tubers.

In 1927 very hot weather prevailed during the last week in June and early July. Plants from the early-planted seed lots suffered severely and their tubers did not develop to full size. The less-advanced, later-planted stocks survived the period and profited by the cooler weather in late July. This would also aid in accounting for the differences in percentages of No. 1 grade tubers. If this supposition is correct it will be seen that results from year to year are likely to vary, because the time, duration, and severity of adverse weather conditions will vary from year to year.

Spindle-tuber was probably present but to the extent of

TABLE 8.—*Rate of maturity in comparative plats at Lincoln in 1927 of seed stocks planted on different dates in 1926. Data are based on weekly estimates of each replication*

Month planted in 1926	Degree of maturity on date observed—1927 on					
	July 11	July 18	July 25	Aug. 1	Aug. 8	Aug. 15
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
April	10.6	22.3	32.3	63.3	74.3	89.9
May	5.9	15.4	24.6	51.7	66.8	82.0
June	2.8	11.3	20.5	45.5	62.1	79.6
July	2.5	12.5	20.8	46.7	61.7	78.3
Check	6.5	16.7	29.2	60.0	76.7	89.5

less than 1 per cent and therefore was not a consequential factor.

Effect of culture and caging with insect-proof cages.—In 1924 Irish Cobbler and Early Ohio potatoes, apparently free from spindle-tuber, were planted in the garden at Lincoln in plats which were given the treatments enumerated in Fig. 15. One piece from each of five tubers of each variety was planted in each of eight cultural plats. The cheese-cloth insect-proof cages were put into place at planting time. Later a few diseased plants were discovered in other seed lots

TABLE 9.—*Production of normal Irish Cobbler potatoes in 1927 from seed stocks planted in different months in 1926 at Lincoln*

Month planted in 1926	Results in comparative plats in 1927			
	Number of 40-hill plats	Mean total yield per 40-hill plat	Mean yield U. S. No. 1 grade per 40-hill plat	U. S. No. 1 grade
	Number	*Pounds*	*Pounds*	*Per cent*
(1)	(2)	(3)	(4)	(5)
April	12	28.3 ± 0.74	16.8 ± 0.62	59.3
May	12	32.0 ± 0.44	21.8 ± 0.44	71.1
June	12	33.7 ± 0.55	25.8 ± 0.64	76.9
July	6	33.5 ± 1.18	26.7 ± 1.13	79.6
Check	6	30.3 ± 1.20	25.1 ± 1.29	82.1

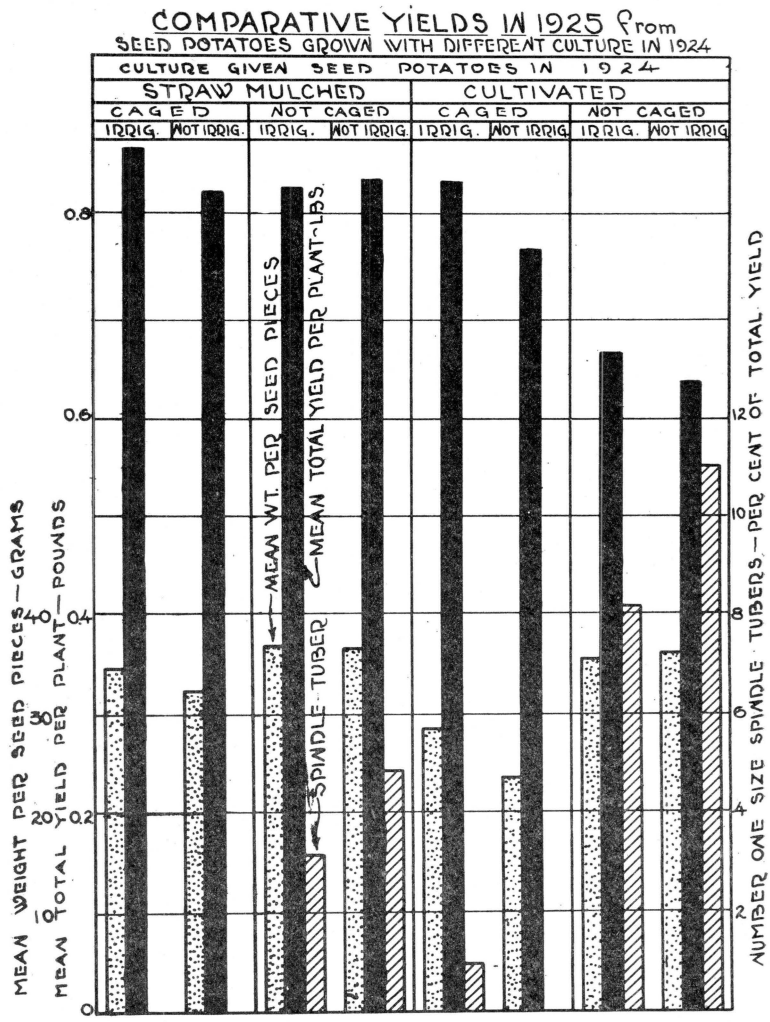

FIG. 15.—Relation of culture and caging in 1924 and size of seed in 1925 to yield and spindle-tuber content of Irish Cobbler potatoes at Lincoln in 1925. (Based on mean of Early Ohios and Irish Cobblers.)

planted close by, and, as will be seen, these quite evidently served as an infection source for some of the uncaged plants. The irrigation water was provided by an overhead sprinkler system.

TABLE 10.—*Ratios of seed weight planted and total yield harvested in the case of various pairs of 1924 treatments. Based on data from comparative plats at Lincoln in 1925. Mean of both Irish Cobbler and Early Ohio varieties*

Treatment pairs used in comparison of	Factors compared	Ratios between various pairs of plats with regard to seed weight and total yield			
		Irrigated		Unirrigated	
		Straw mulched	Cultivated	Straw mulched	Cultivated
Caged and uncaged plats	Seed weight	0.94:1	0.79:1	0.88:1	0.66:1
	Total yield	1.05:1	1.26:1	0.98:1	1.21:1
		Straw mulched		Cultivated	
		Caged	Uncaged	Caged	Uncaged
Irrigated and unirrigated plats	Seed weight	1.07:1	1.00:1	1.19:1	0.99:1
	Total yield	1.05:1	0.99:1	1.09:1	1.04:1
		Irrigated		Unirrigated	
		Caged	Uncaged	Caged	Uncaged
Straw mulched and cultivated plats	Seed weight	1.22:1	1.03:1	1.36:1	1.02:1
	Total yield	1.04:1	1.25:1	1.07:1	1.32:1

In 1925 comparative plantings of hill units of 10 hills each were made at Lincoln. Thruout this experiment the seed-pieces were somewhat heavier in the uncaged, mulched, and irrigated lots than in their companion lots, due to the production of more and larger tubers the previous year. In spite of this advantage the open-grown lots were outyielded by the caged lots. After giving consideration to this difference in seed-piece weight by calculating the ratio of weight of seed of one lot with another lot and comparing that ratio with the yield ratios of the same lots (Table 10), it seems quite certain that many of the yield increases were due to larger seed-pieces. (Table 10 is based on weighted mean of both varieties, whereas Fig. 15 presents only the data from the Irish Cobblers.)

All of these increases, however, cannot be attributed to difference in seed weight, as the ratios of the yield from the straw-mulched, not caged, lots (both irrigated and non-irrigated) to the cultivated stocks were much greater than the seed-weight ratios for the same lots. The same circumstances prevailed with the caged and uncaged cultivated lots. These differences were possibly due to spindle-tuber, the un-

caged, mulched lots having produced 3.2 per cent (irrigated stock) and 4.9 per cent (non-irrigated stock) of No. 1 size "spindle tubers" as compared with 8.2 per cent and 11 per cent respectively from the uncaged, cultivated stocks (Fig. 15). Likewise in the case of the caged cultivated lots the irrigated stock produced one per cent of No. 1 size (doubtful) "spindle tubers" and the non-irrigated produced no "spindle tubers," whereas the uncaged lots produced respectively 8.2 per cent and 11 per cent of "spindle tubers" as previously noted.

This experiment was repeated in 1925-26. As the results were practically the same as in 1924-25, no further report will be made.

With these relatively healthy stocks it appears that cultural conditions were minor factors, if factors at all, in directly affecting seed quality of tubers produced.

Effect of soil nitrates.—Data on hand show that in 1926 the soil nitrate content in the Lincoln plats was higher than usual and that it generally decreased from late May to the end of the season. Both mulching with straw and irrigation reduced the nitrate content with regularity, the lowest content in September being in the irrigated mulched soil.[3] These same treatments increased the soil moisture content and decreased the soil temperature. The addition of nitrate of soda at the rate of 600 pounds per acre increased the nitrate content of the cultivated and straw-mulched soils. Nitrate addition increased the nitrate content of straw-mulched soils to about that of the untreated cultivated soils.

In the 1927 comparative plats, there was no evident correlation between soil nitrate content the previous year and the productivity of the seed stock thus produced. (Table 11.) In this series of plats early harvesting seemed to be the only treatment that was associated with increased seed productivity. There was no spindle-tuber in evidence in any of the lots in the comparative plats.

Accumulative effect of cultural conditions upon healthy seed potatoes.—In the spring of 1926 seed pieces from 16 healthy Irish Cobbler tubers were planted by groups of three. One of each of these three hills was cultivated, one was straw mulched, and one was straw mulched and covered with an insect-proof cage. At Lincoln these groups of three plants from each tuber were planted close together in a corn field and these were isolated from the plants growing from other tubers by planting the groups 50 feet apart in a corn field. At Alliance the individual hills were also isolated in a corn field.

[3] Soil nitrate determinations were made under the direction of Prof. J. C. Russel of the Department of Agronomy.

TABLE 11.—*Yields from seed stocks produced in high and low nitrate soils, with and without straw mulching and with early and late harvesting. (Yield in pounds per 40-hill plat)*

1926 seed producing treatments		Yield in 1927 comparative plats from seed stocks grown	
Soil management	Harvesting date	Without additional nitrates	With additional nitrate of soda
Seed stock grown with irrigation			
		Pounds	*Pounds*
Straw mulched	July 7	24.8 (3)*	22.0 (4)*
	Sept. 16	20.9 (4)	21.3 (4)
Cultivated	July 7	22.5 (4)	24.6 (4)
	Sept. 16	17.2 (4)	19.1 (4)
Seed stock grown without irrigation			
Straw mulched	July 7	23.3 (2)	22.4 (3)
	Sept. 16	20.5 (4)	22.0 (4)
Cultivated	July 7	23.0 (2)	22.4 (2)
	Sept. 16	25.5 (4)	22.1 (4)
Weighted mean yield from seed stocks grown with and without irrigation			
Straw mulched	July 7	24.2 (5)	22.2 (7)
	Sept. 16	20.9 (8)	21.7 (8)
Cultivated	July 7	22.6 (6)	23.8 (6)
	Sept. 16	21.4 (8)	20.6 (8)

* Parenthetical number refers to the number of plats planted with each seed lot.

In order to test the accumulative effect one seed piece from each 1926 plant was planted so as to receive the same culture in 1927 as did the plant on which it was produced.

In 1927 comparative tests of the progeny of all 1926 hills were conducted at Lincoln, 10 hills being planted with one pound of tubers from each original hill, thus supplying 16 plats of 10 hills each from each treatment source. In 1928 the comparative tests were conducted at North Platte when 5 plats of 44 hills each were grown from mass samples produced by the 1927 cultural seed treatments.

The yield differences were relatively small—both in 1927 after one year and in 1928 after two years of differentiated culture. (Table 12.)

TABLE 12.—*Production from seed potatoes grown under different cultural conditions for one and two years*

Conditions under which seed potatoes were produced	Mean total yields in comparative trials	
	1927 at Lincoln	1928 at No. Platte
	16 10-hill plats	5 44-hill plats
	Pounds	*Pounds*
Lincoln—cultivated—uncaged	7.92	58.8
Lincoln—straw mulched—uncaged	7.62	57.4
Lincoln—straw mulched—caged	8.18	62.4
Alliance (Western Nebraska dry land)	8.11	62.6

Spindle-tuber was not present in these lots of seed and hence was not a factor in causing the slight yield differences. The straw-mulched caged seed lots were as productive as those produced on dry land at Alliance (in western Nebraska). Apparently, when disease was not present, lots of seed did not degenerate to any significant extent when grown at Lincoln.

SEED POTATOES GROWN AT UNION WITH VARIED CULTURE

Early Ohio potatoes of supposedly disease-free lines were planted in isolated plats in the orchard on the University Fruit Farm at Union, in the extreme eastern portion of the state. However, the lines of Early Ohio seed planted in 1923 and 1924 were found to contain considerable spindle-tuber, which was rogued out as well as possible during the early part of the summer. In 1925 a line of Irish Cobbler seed was planted. This line had very little spindle-tuber.

Accumulative effect of culture and season upon a line of seed infected with spindle-tuber.—In 1924 some of the potatoes were planted in comparative plats at Scottsbluff and North Platte. Small amounts of each lot of seed were again planted at Union in plats that were given the same treatment as had been used the previous year in producing each such seed lot. In addition in 1924 some additional planting and harvesting dates were added as shown in Table 13 (Columns 7 and 8). The seed stocks thus produced under the same cultural conditions in two successive years were planted in comparative trial plats at North Platte in 1925. After one

TABLE 13.—*Effect of different planting and harvesting times as well as cultural methods upon Early Ohio seed stocks grown at Union for one and two years*

Seed production treatment at Union in 1923		Comparative trials in 1924				Seed production treatment at Union in 1924		Comparative trials at North Platte in 1925		
		at Scottsbluff		at North Platte						
Planting time	Harvesting time	Spindle-tubers No. 1 size	Total yield per acre	Spindle-tubers No. 1 size	Total yield per acre	Planting time	Harvesting time	Spindle-tubers No. 1 size	Total yield per acre	U. S. No. 1 primes
(1)	(2)	*Per cent* (3)	*Bushels* (4)	*Per cent* (5)	*Bushels* (6)	(7)	(8)	*Per cent* (9)	*Bushels* (10)	*Per cent* (11)
SEED GROWN WITH ORDINARY CULTIVATION AT UNION										
April	August	7.4	276	.....	.....	April	August	18.7	268	49.9
							October	23.2	255	41.8
						June	October	14.5	330	47.6
	October	10.1	289	6.9	235	April	August	18.1	305	53.1
							October	16.8	298	56.7
July	October	1.8	301	1.4	241					
SEED GROWN UNDER STRAW MULCH AT UNION										
April	August	7.8	291	.....	.....	April	August	6.7	390	66.5
							October	17.1	364	50.8
						June	October	8.9	416	51.0
	October	3.1	279	6.6	269	April	August	10.0	294	56.9
							October	14.1	362	51.3
July	October	0.5	289	0.1	246					

year at Union the seed potatoes planted in July and harvested in October were slightly more productive (3 out of 4 cases) than those from the April plantings (Table 13) as seen in the Scottsbluff plat. In the trials at North Platte the July-planted stock of the cultivated series was slightly more productive, while in the straw-mulched series it was the less productive. In the case of April-planted seed stocks time of harvesting did not appear to have been much of a factor in affecting either spindle-tuber content or yield at Scottsbluff. Much spindle-tuber infection was apparently prevented by late planting, but early August harvesting exerted no consequential effect.

TABLE 14.—*Yield at North Platte in 1926 of healthy Irish Cobbler seed potatoes produced by planting and harvesting at different dates with varied culture in isolated plats*

1925 history				Production at North Platte in 1926			
Place	Dates		Culture	Total yield bu. per acre		Percentage of the yield of each lot	
	Planting	Harvesting		Total yield	U. S. No. 1 primes	Spindle tubers No. 1 size	No. 2 and No. 3 size
(1)	(2)	(3)	(4)	*Bu.* (5)	*Bu.* (6)	*P. ct.* (7)	*P. ct.* (8)
Union	April 10	Aug. 3	Mulched	447	337	0.12	11.1
Union	April 10	Oct. 15	Mulched	377	328	0.90	10.7
Union	April 10	Aug. 3	Cultivated	384	340	0.63	11.2
Union	April 10	Oct. 15	Cultivated	363	286	2.46	17.0
Union	Aug. 5	Oct. 15	Cultivated	377	349	0.77	5.7
Lincoln	April	October	Mulched	285	239	4.29	11.2
Lincoln	April	October	Cultivated	277	189	7.79	24.3
Bushnell*	June	October	Cultivated	252	296	1.77	8.89
Wyoming—checks				346	316	1.22	7.27

* Bushnell plat was on dry land near Bushnell in Kimball county.

After the potatoes were grown at Union for a second year and then (in 1925) compared at North Platte, the cultivated lots produced a higher percentage of "spindle tubers" and a lower total yield (except one out of 5 pairs) than the comparable straw-mulched seed lots. There was a tendency toward higher spindle-tuber content and less so toward lower production due to late harvesting. Late planting (June) in 1923 gave a lower spindle-tuber content and distinctly increased yield in 1924.

These seed stocks were still reasonably productive at the end of the second year, but because of the low percentage of

prime tubers they could hardly be considered desirable. They would undoubtedly have been very unsatisfactory had they been carried over for a third year.

Apparently a lot of seed which contains only a small percentage of spindle-tuber may be used fairly advantageously after one year at Union. Roguing is not an adequate means of maintaining such a lot of seed for more than one year.

Effect upon healthy seed stock.—In 1925, Wyoming-grown Irish Cobblers were planted in isolated plats at Union, Lincoln, and Bushnell under the conditions specified in Table 14. When planted at North Platte for comparative trials in 1926 these stocks actually yielded more than either the check from seed from the original Wyoming source, or the western Nebraska-grown lots. August-harvested stocks were somewhat more productive than the October stocks, the early-August-planted lot was slightly superior to the April-planted lot, and the straw-mulched seed was slightly superior to cultivated stocks.

The percentage of spindle-tuber was very low but increased as productivity decreased. It was also most prevalent in the stocks that had been in the field the longest time the previous year. The spindle-tuber content increased less at Union than at Lincoln or Bushnell, in fact was no greater than in the original Wyoming stock.

DISCUSSION

Good seed potatoes can be produced in eastern Nebraska if disease-free seed stock is used and seed fields are isolated from other potato fields or from plants that might serve as sources of infection. Such seed stocks should remain productive for a considerable length of time. Culture, time of planting, etc., will cause variation in the maturity of seed potatoes, which influences the period of dormancy. This in turn alters the degree of apical dominance manifested by seed tubers at planting time—thus affecting the number of stems and tubers per plant. The degree of dormancy also affects the emergence rate and probably the time of tuber setting. These environmental effects are evident only in the next crop and at the present time there is no evidence indicating that cultural conditions exert a permanent change in healthy potato-seed stocks. When spindle-tuber is present, however, cultural conditions are of more far-reaching importance.

Production of seed potatoes for one year in isolated, rogued seed plats is probably a safe procedure in eastern Nebraska if seed stocks free from spindle-tuber are used. Whether it will be practical to grow such seed will depend upon the yield of seed potatoes secured and also the annual price fluctuations.

BIBLIOGRAPHY

Appleman, C. O.
1924. Potato sprouts as an index of seed value. Maryland Agr. Exp. Sta. Bul. 265.
——— and E. V. Miller
1926. A chemical and physiological study of maturity in potatoes. Jour. Agr. Research, Vol. 33, No. 6, pp. 569-577.
Botjes, J. O.
1923. Die verwendung unreifer kartoffeln als saatgut. Deut. Landw. Presse, 50:118-119.
———
1923. Experiments regarding the use of immature seed seen at Oostavold during conference. Report of International Conference of Phytopathology and Economic Entomology, Holland, pp. 143-147.
Brown, B. A.
1928. Report of the director for 1927. Conn. (Storrs) Agr. Exp. Sta. Bul. 149.
Bushnell, John
1923. Effect of temperature on the potato plant. Amer. Soc. Hort. Sci. Proc., p. 307.
———
1928. Do potato varieties degenerate in warm climates? Jour. Heredity, Vol. 19, No. 3.
Butler, O.
1926. Field crops experiments in New Hampshire in 1925. N. H. Exp. Sta. Bul. 221, pp. 13-19.
Clark, Charles F.
1921. Development of tubers in the potato. U. S. Dept. Agr. Bul. 958.
Edmundson, W. C.
1922. Report of experiments at Colorado Potato Experiment Station. Nebr. Potato Impr. Assoc., 4th Ann. Rpt., pp. 40-44.
———
1924. Work of the Colorado Potato Experiment Station. Nebr. Potato Impr. Assoc., 6th Ann. Rpt., pp. 49-56.
Elmer, O. H.
1922. Mosaic cross-inoculation and insect transmission studies. Science, Vol. 56, No. 1448, pp. 370-372.
Emerson, R. A.
1914. Home mulched vs. northern seed potatoes for eastern Nebraska. Nebr. Agr. Exp. Sta. Bul. 146.
Folsom, Donald
1924. The importance and natural spread of potato degeneration diseases. Maine Agr. Exp. Sta. Bul. 316.
Goss, R. W.
1926. Transmission of potato spindle-tuber disease by cutting knives and seed-piece contact. Phytopathology (Abstracts), Vol. 16, p. 6.
Janssen, J. J.
1929. Invloed der bemesting op de gezondheid van de aardappel.
(Institute voor phytopathologie, Laboratorium voor bycologie en aardappelonderzoek mededeeling 43.) "Tijdschrift over plantenziekten," 35e Jaargang, 1929. pp. 119-151.
Abridged article in "Die Ernährung der Pflanze, 25, No. 9, May 1, 1929, pp. 198-202.

Knorr, P.
1922. Versuchsergebnisse auf dem gesamtgebiete des kartoffelbaues im jahre 1919 und 1920. Arb. Forschungsinst. Kartoffelbau, Hefte 5 und 6. Berlin.
Krantz, Fred A.
1922. A preliminary study of field plot technic in potato yield tests. Potato Assoc. Amer. Proc., p. 42.
Müller, H. C., and Molz, E.
1924. Effects of stimulation and depression on productivity in potato culture. (Title translated.) Deut. Landw. Presse, 51, No. 9, p. 91.
Münter, R.
1922. Unreife oder reife kartoffeln als saatgut. (Immature or mature potatoes for seed.) Deut. Landw. Presse, 49:9-10.
Parker, W. H.
1922. Potatoes—maturity and yield trials. Jour. Natl. Inst. Agr. Bot., Vol. 1, No. 5, p. 19.
Profeit, W. J., and Findlay, W. M.
1923. Some factors affecting the value of potatoes for seed purposes. Scot. Jour. Agr., Vol. 6, No. 1, pp. 54-63.
Rosa, J. T.
1925. Potato production in California. Cal. Agr. Exp. Sta. Cir. 287, p. 15.

1928. Relation of tuber maturity and of storage factors to potato dormancy. Hilgardia, Vol. 3, No. 4, pp. 100-124.
Salaman, Radcliffe N.
1926. Potato varieties. Cambridge University Press. (The Macmillan Company, American representatives.)
Schultz, E. S., and Folsom, Donald
1923. Transmission, variation, and control of certain degeneration diseases of Irish potatoes. Jour. Agr. Research, Vol. 25, No. 2, pp. 43-117.
Stuart, Wm., Edmundson, W. C., Lombard, P. M., and Dewey, G. W.
1927. Source, character, and treatment of potato sets. U. S. Dept. of Agr. Tech. Bul. No. 5.
Wellenseik, S. J.
1925. Potato storage and blind tubers. (Title and article translated by W. A. McCubbin.) Original article: Die kartoffel. No. 16. Translation in Potato News Bul. 2, No. 10, p. 396.
Werner, H. O.
1924. Spindle-tuber, the cause of "run out" potatoes. 6th Ann. Rpt. Nebr. Potato Impr. Assoc., pp. 57-80.

1924. Relation of environment to spindle-tuber symptoms. Potato Assoc. Amer. Proc., pp. 102-106.

1925, a. The spindle-tuber disease, one cause of "run out" seed potatoes. Nebr. Agr. Exp. Sta. Bul. 207.

1925, b. Relation of environmental factors to productiveness of seed potatoes. Potato Assoc. Amer. Proc., pp. 10-22. Paper No. 20, Jour. Series, Nebr. Agr. Exp. Sta.
Wessel, Philip H., and Hartwell, Burt L.
1927. Viability and composition of "seed" potatoes as affected by climatic conditions and by various other factors. Jour. Amer. Soc. Agron., Vol. 19, No. 9, p. 761, p. 780.